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THE FRAGMENTATION OF METAL CYLINDERS USING THERMOBARIC EXPLOSIVES

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Defence Research and
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Outline

- Research goal
- Basic principles of TBX
- Experimental set-up
- Secondary combustion
- Fragment mass results
- Fragment velocity results
- Conclusions
- Future work

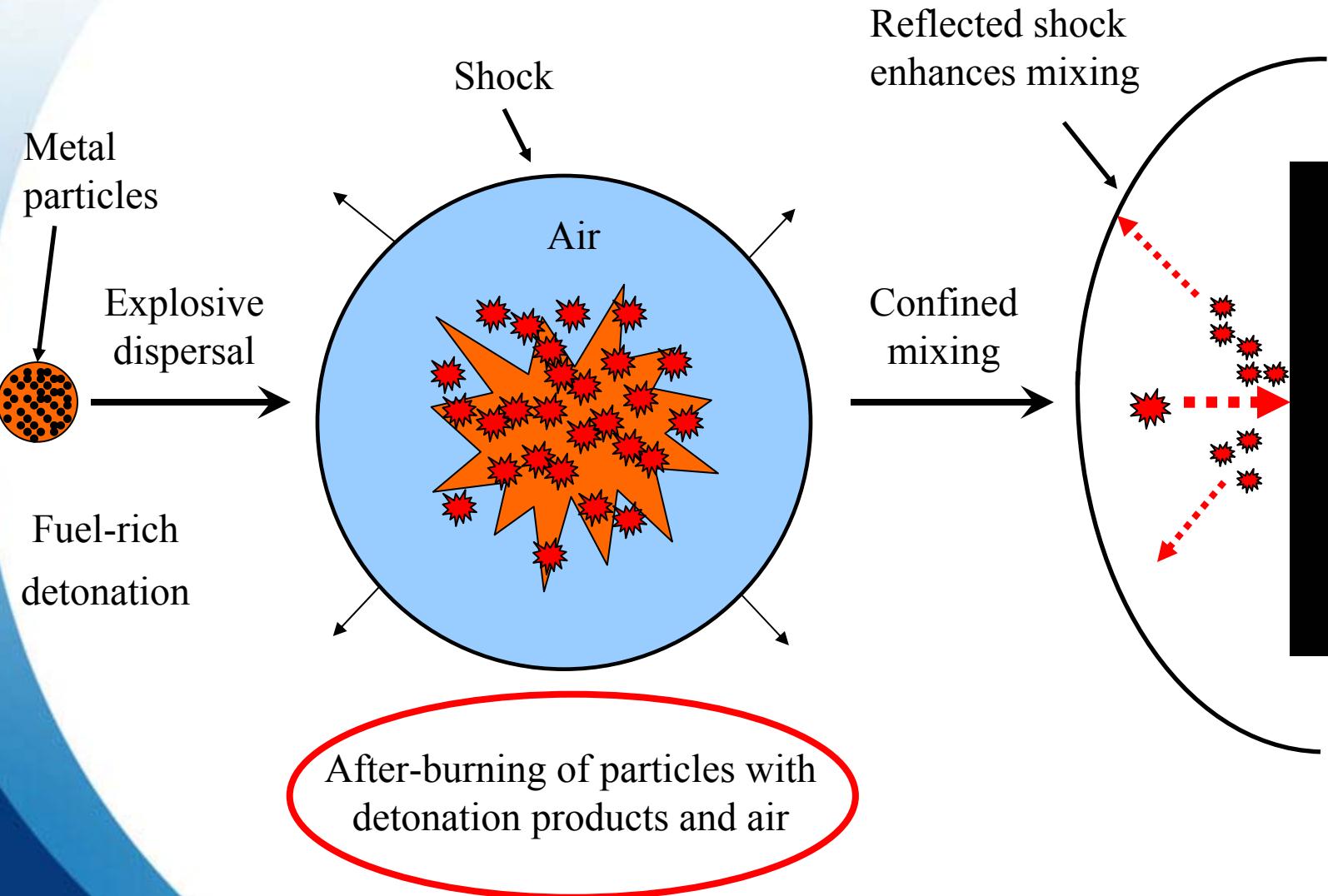


Research Goal

To assess the ability of TBXs to generate fragments.

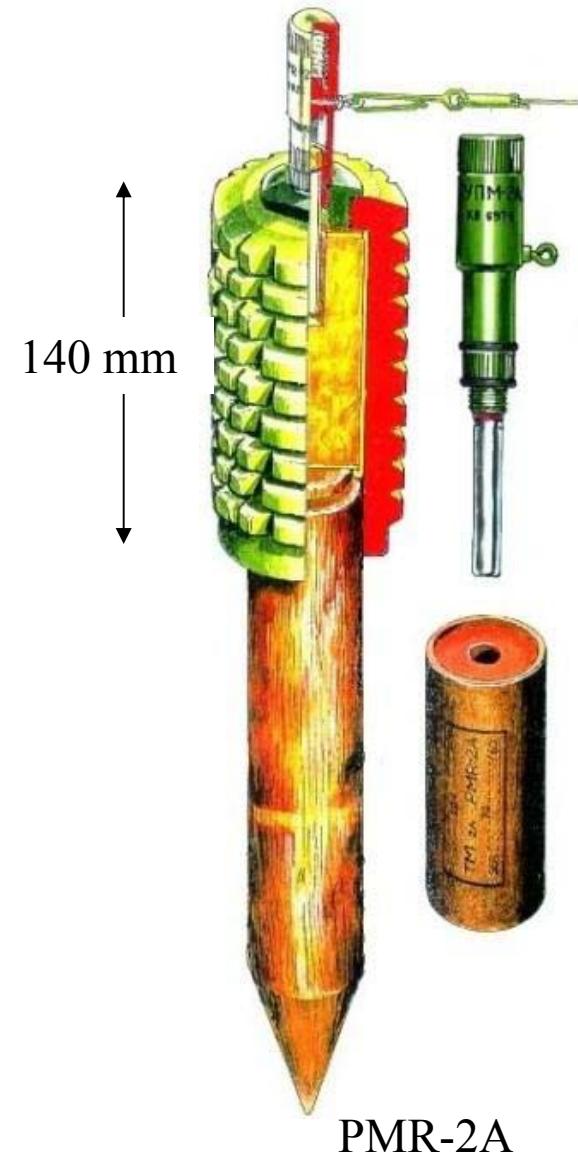
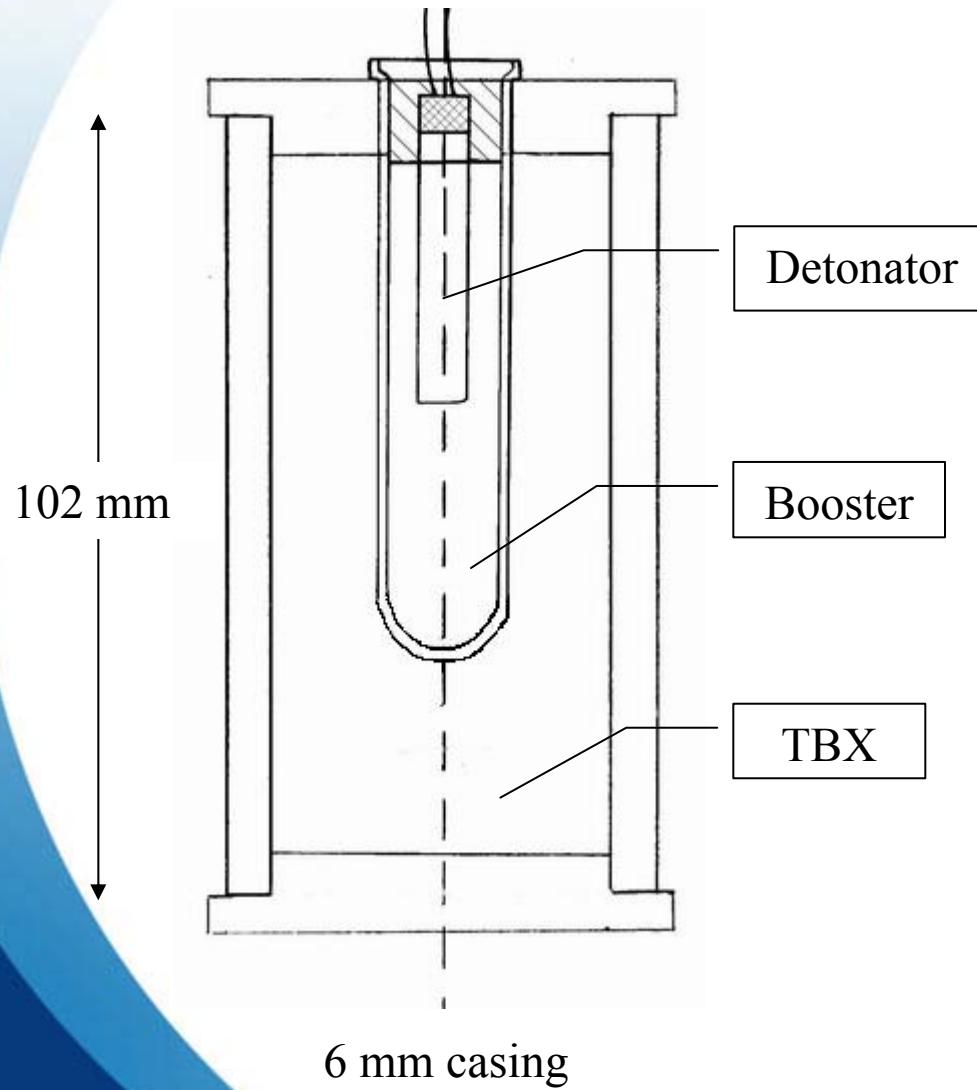


Basic TBX Concept



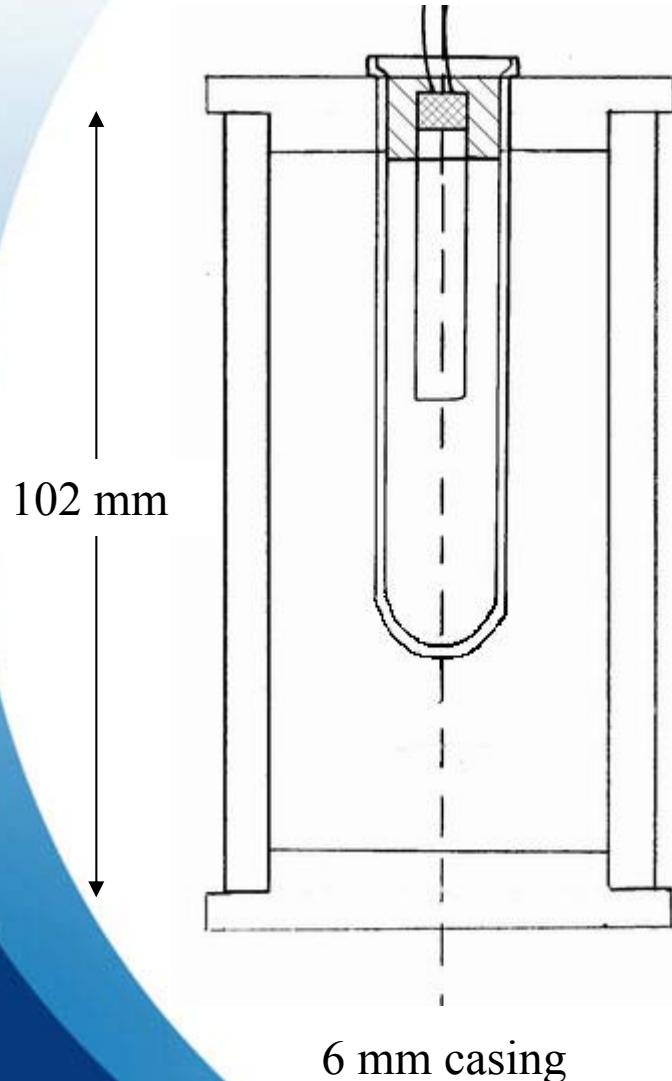


Experimental Charge





Trial Variables



- Explosives
 - TBX 1, 2, 3
 - C4 (baseline)
- Wall thickness
 - 3.8 mm, 6 mm,
8 mm, and 9.5 mm
- Casing material
 - 1026 steel
 - Ductile cast iron (DCI)
 - Grey cast iron (GCI)



TBX formulations

TBX 1

Monopropellant and magnesium particles

TBX 2

Nitromethane and aluminium (60/40 %wt)

TBX 3

Monopropellant, aluminium and RDX



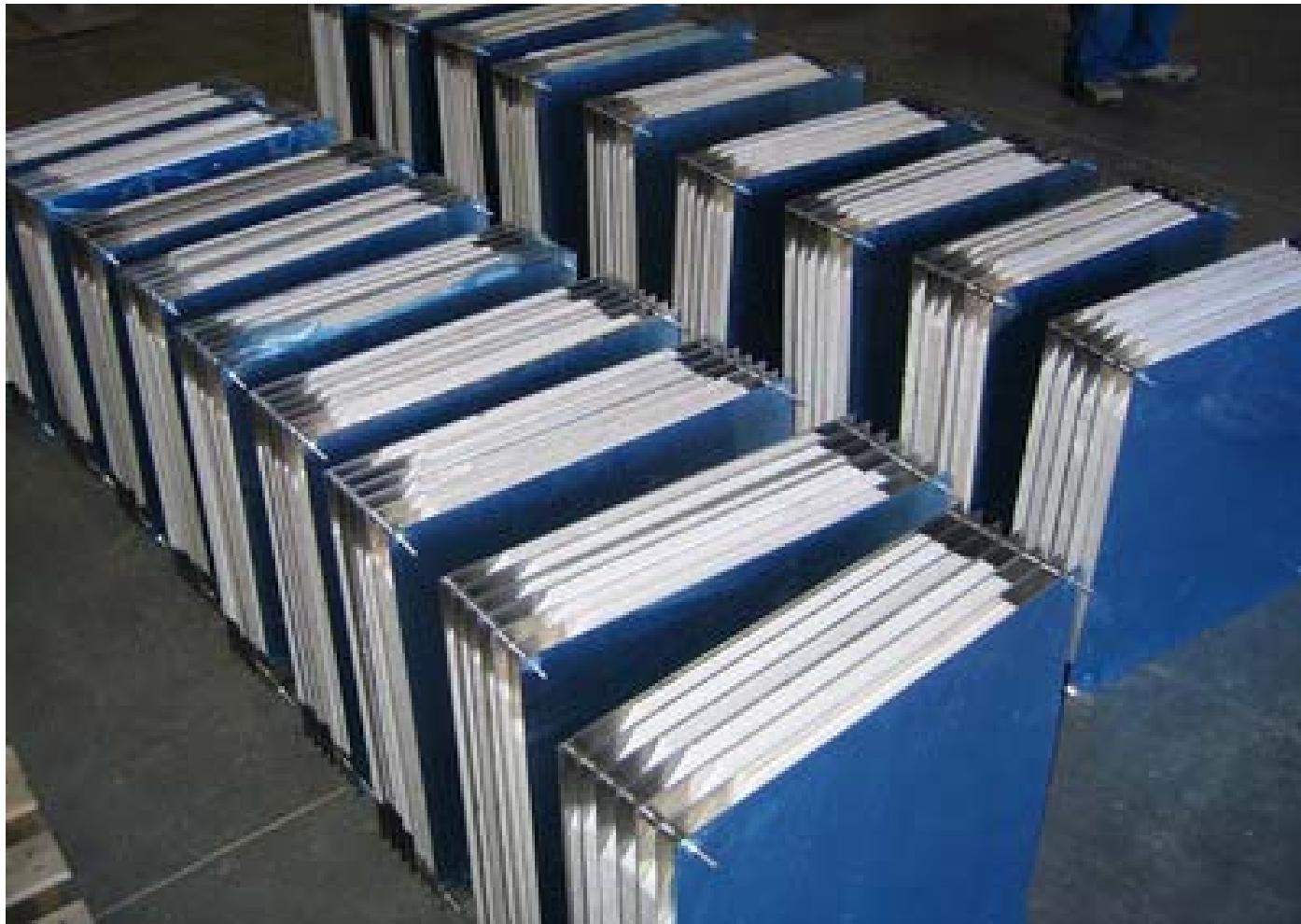


Mine Effects Site





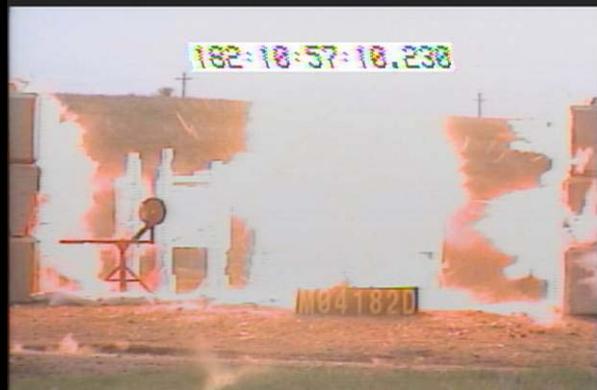
Witness Packs





Secondary Combustion

First fragment impacts





Witness Pack Analysis

Software converts hole size and depth of penetration to mass and velocity

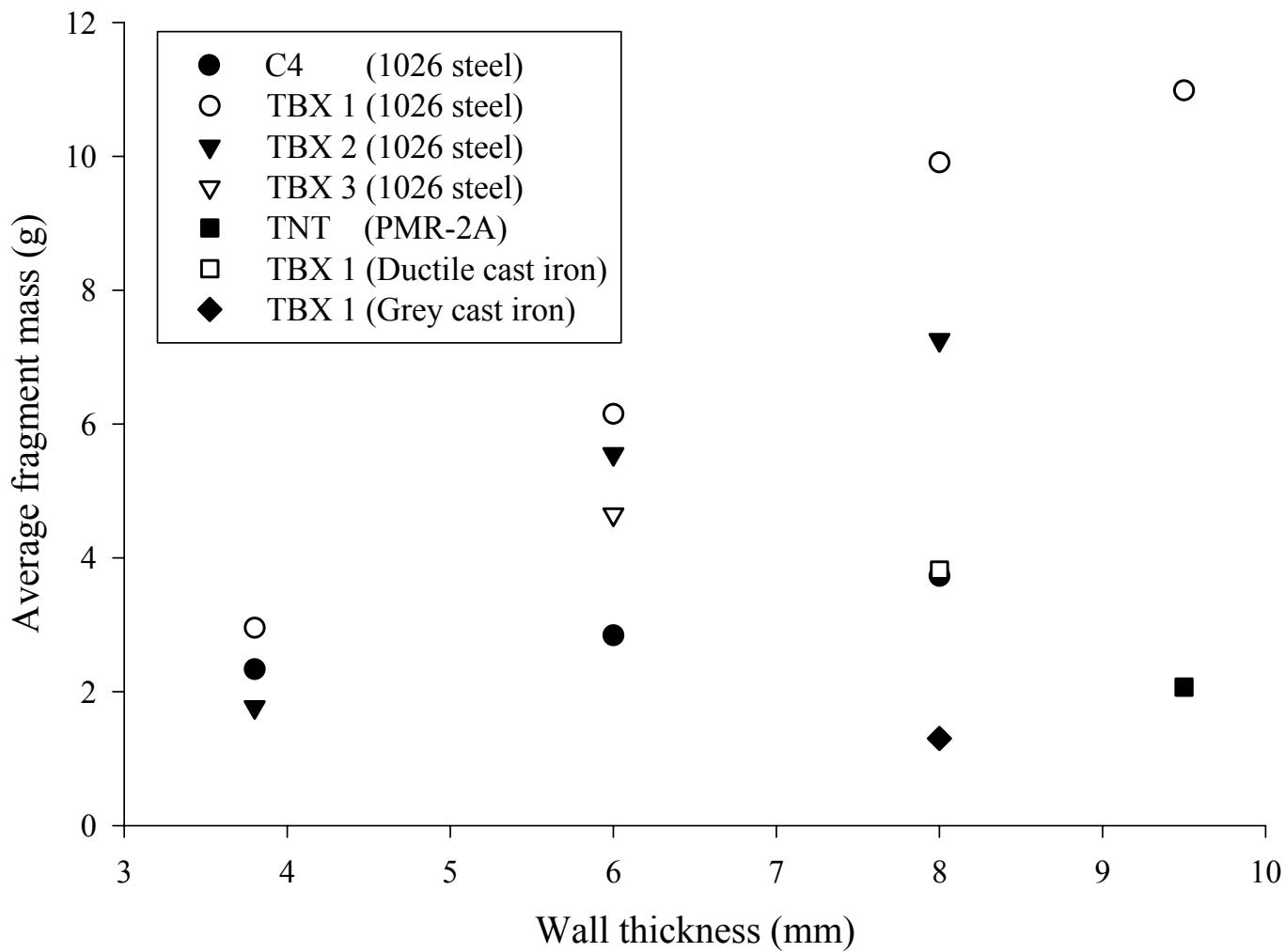
- Mass distribution results were compared to literature values
- The average velocities were compared to other methods.



C4-filled, 6 mm, 1026 steel casing

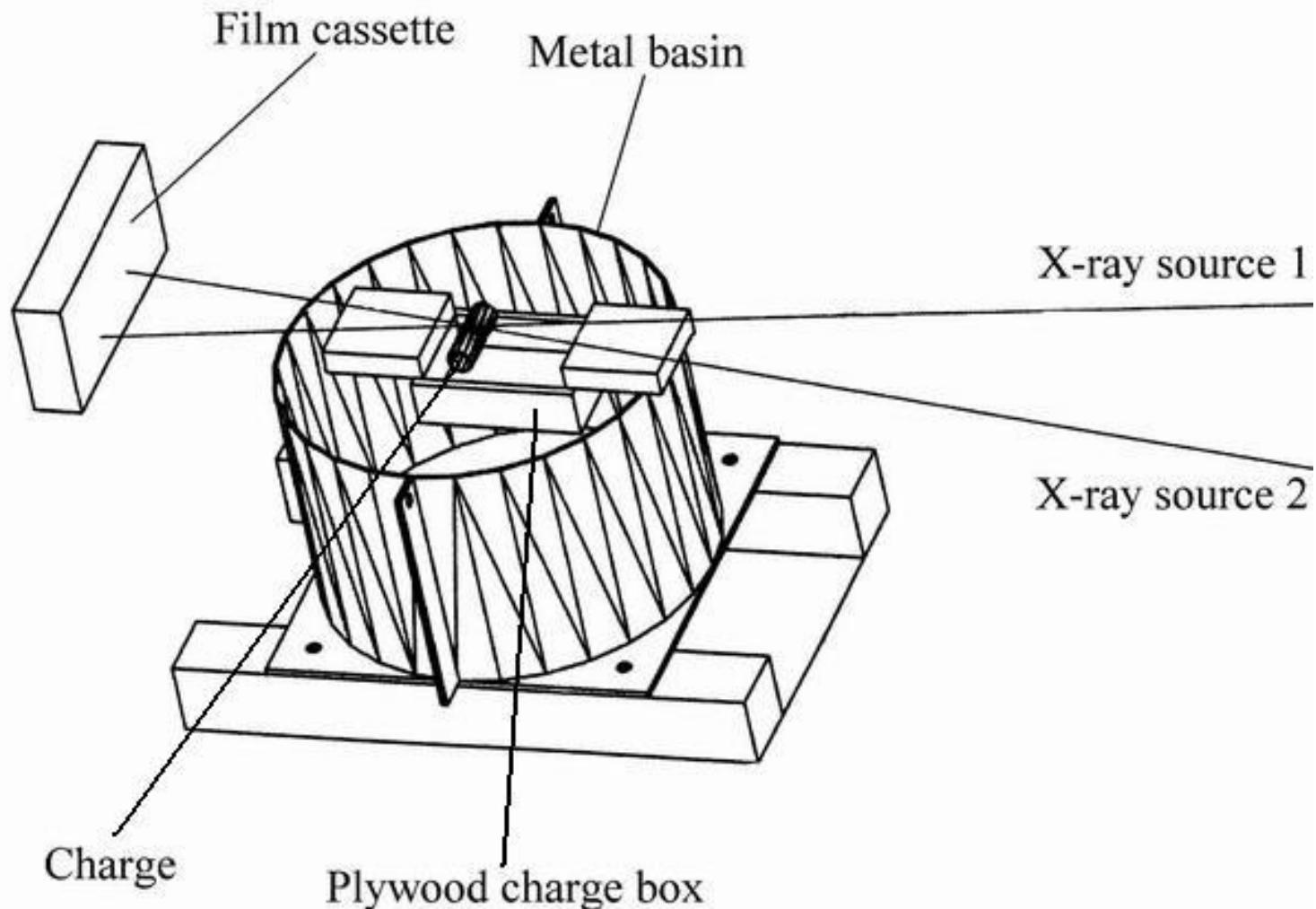


Average Fragment Mass





Flash X-ray Site (1/2)

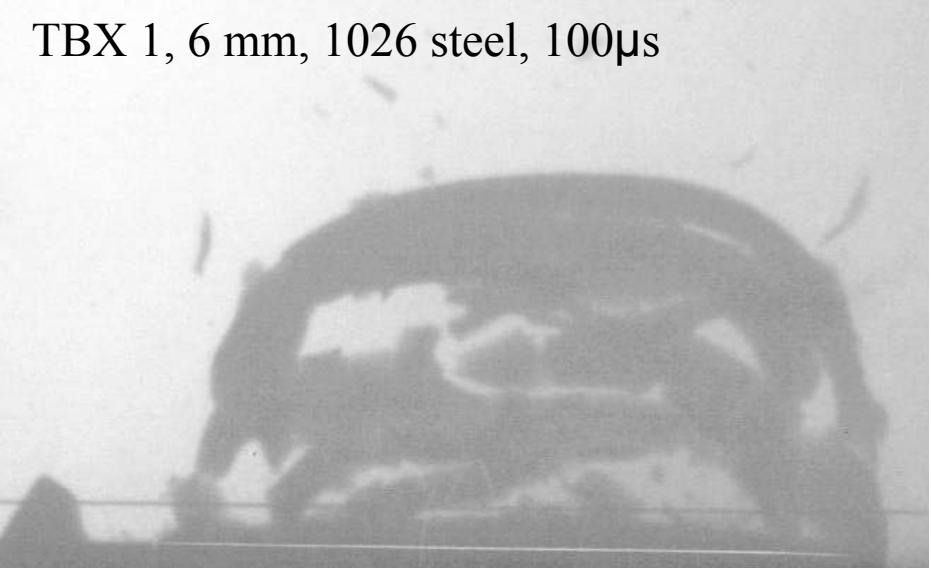




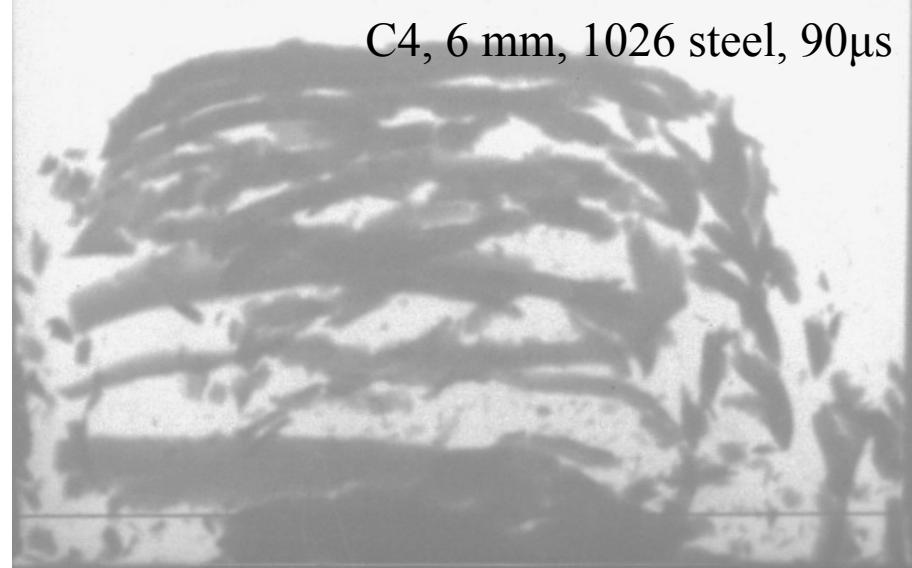
Flash X-ray Site (2/2)



TBX 1, 6 mm, 1026 steel, 100 μ s



C4, 6 mm, 1026 steel, 90 μ s

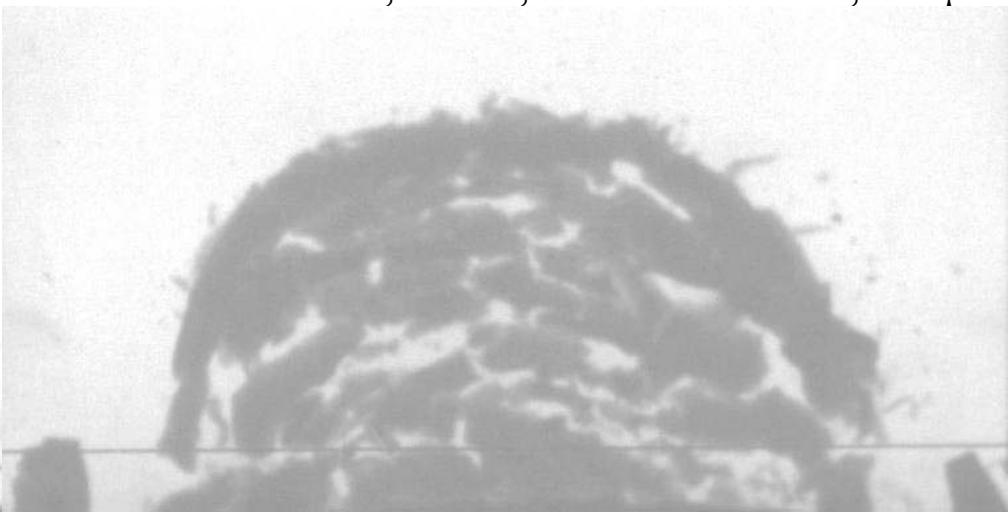


X-ray Images

TBX 1, 3.8 mm, 1026 steel, 100 μ s



TBX 1, 6 mm, ductile cast iron, 100 μ s





Predicting Fragment Velocity

Gurney equation

- Simple and long-standing
- Geometry-specific

$$v = \sqrt{2E} \left(\frac{M}{C} + \frac{1}{2} \right)^{-\frac{1}{2}}$$

M = mass of casing

C = mass of explosive

$\sqrt{2E}$ = Gurney constant

SplitX

- Gurney-based computer code that considers:
 - End confinement
 - Shock wave interaction and propagation
 - User-controlled geometry



Fragment Velocity (m/s)

Explosive	Wall thickness	Casing	Gurney ^a (+/- 12%)	SplitX ^a	Witness packs ^b	X-ray images ^a (+/- 50)
C4	6 mm	1026	1460	1360	610	1400
C4	8 mm	1026	1260	1150	590	---
TBX 1	3.8 mm	1026	1010	990	450	1000
TBX 1	6 mm	1026	700	770	430	800
TBX 1	6 mm	DCI	740	820	---	800
TBX 1	6 mm	GCI	640	810	---	750
TBX 2	6 mm	1026	990	930	460	---
TBX 3	6 mm	1026	1030	970	490	1000

a – Maximum fragment velocity

b – Average fragment velocity



Conclusions



- TBXs are capable of fragmenting metal casings:
 - Fragment mass distributions were consistent with literature values; and
 - Fragment velocities were well predicted using means that assume an instantaneous release of detonation energy.



Future Work



- Determine how the casing thickness and material disrupt the TBX shock wave.
 - Sacrificing the “thermobaric effect” to have fragments
- Determine how the fragmentation trends of the base explosives are altered by the additives.
 - Run trials with pure NM, and with silicon as an additive
- Determine why the casing material appears to have little effect on fragment velocity.
 - High strain rate failure and gas dynamics problem



Acknowledgements

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 - Dr. J. Anderson for scientific support

DEFENCE



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QUESTIONS ?

End of Presentation



Follow-on Slides



Fragment Energy (J)

Explosive	Casing thickness	Material	Average mass (g)	Max velocity (m/s)	Energy (J)	Number of fragments
C4	3.8 mm	1026	2.3	1750	3500	180
C4	6 mm	1026	2.8	1400	2700	240
C4	8 mm	1026	3.7	1200	2700	260
TBX 1	3.8 mm	1026	3.0	1000	1500	140
TBX 1	6 mm	1026	6.7	800	2100	100
TBX 1	8 mm	1026	9.9	650	2100	100
TBX 1	9.5 mm	1026	11.0	550	1700	110
TBX 1	8 mm	DCI	3.8	800	1200	220
TBX 1	8 mm	GCI	1.3	750	370	670
TBX 2	3.8 mm	1026	1.8	1200	1300	230
TBX 2	6 mm	1026	5.6	970	2600	120
TBX 2	8 mm	1026	7.3	850	2600	130
TBX 3	6 mm	1026	4.7	1000	2400	150
TNT (PMR 2A)	9.5 mm	GCI	2.1	570	340	740



Fragment Mass Distribution Mott Approach

$$N(m) = \frac{M_o}{2M_K^2} e^{-\left(\frac{\sqrt{m}}{M_K}\right)}$$

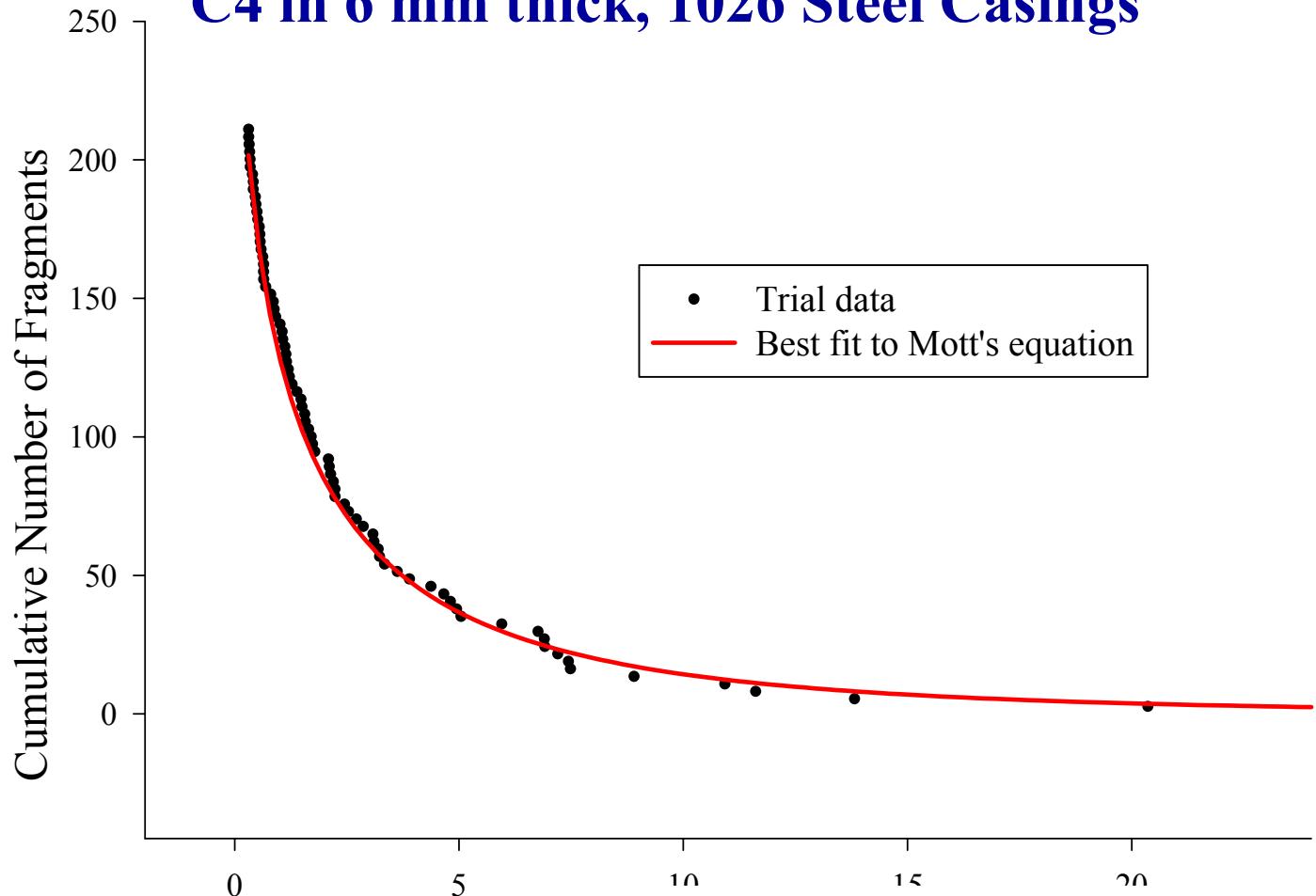
$N(m)$ = number of fragments
heavier than mass m
 M_o = casing mass

$$M_K = B t^{\frac{5}{6}} d^{\frac{1}{3}} \left(1 + \frac{t}{d} \right)$$

t = casing thickness
 d = casing interior diameter
 B = Mott coefficient



Fragment Mass Distribution C4 in 6 mm thick, 1026 Steel Casings





Fragment Velocity vs. Time TBX 1 in 1026 steel casings

